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An Evaluation of Zero Grazing

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THERE CAN BE no doubt that the system of cow management known as zero grazing has certain advantages over traditional grazing systems; for example, grass is available for feeding from fields previously too distant or inaccessible to cows, and no fences or watering points are needed. With increasing pressure from grassland workers that utilization should match up to modern standards of grass production, considerably more is likely to be heard about zero grazing in the future. In these pioneer days it is therefore necessary to bring into focus the problems associated with it.

Briefly these problems fall into five groups:

1. The practical problems of keeping cows contented and healthy in a confined space. (It is not the purpose of this paper to go into these.)
2. The need to plan a cropping programme so that there is grass or forage to cut for the longest period possible and also no periods when supplies of keep fail.
3. Palatability of feed.
4. High milk production from grass.
5. Economics.

Need to Plan

The planning referred to in 2 above does not require much elaboration. Theoretically, it should be easier to achieve than on a normal grazing system. Freedom from poaching and winter defoliation encourages earlier growth, and during the dry summer period alternative crops can be grown to supplement the grass. Lucerne, maize and cereal crops can be fully exploited. Nevertheless, the farmer must always see that feed supplies are sufficient, otherwise a crisis may occur when the winter keep supplies are exhausted before the spring "grazing" has grown sufficiently to cut. Hence it is always necessary to plan for a surplus of feed at all times of the year as an insurance. But this surplus can often be wasted, thus losing much of the advantage of the better grass utilization which has been aimed at. Wasting the surplus could possibly be avoided if a reserve of silage were always kept. It must also be remembered that in spring, zero grazing may start 2–3 weeks later than conventional grazing, since the cow can eat grass which is too short to mow.

Palatability

Because the farmer has to plan a surplus of keep, there may be persistent difficulty in using it up, particularly as it may be less palatable. For instance, if the crop cutting and gathering is to be done with ordinary haymaking or silage-making equipment, the herbage must be

6–9 in. long before the work can start otherwise the machine will be unable to pick it up. Such grass is already at the silage stage, and if it is growing rapidly, it would soon be hay and its attractiveness to cows diminished.

Secondly, under zero grazing, the cow's selectivity has to a large extent been nullified. Unable to look around for an alternative bite which may be more attractive, she will do the obvious thing and reduce her food intake. Loss of palatability can occur under a variety of circumstances, as when the feed is contaminated with soil, old stubble, leaves, and unpalatable or poisonous weeds. It has also been noticed that the cow does not appear to relish wet grass, nor does she like grass which has been mauled or allowed to heat in a trailer, and there is reason to doubt whether the grass cutting and collecting equipment on the ordinary farm is adequate for the job. We need a machine that can cut and collect pasture grass and yet does not present the cow with everything that can be removed from the field. Even then the problem remains of differentiating between the plants in the field. Today, the best machine we have to do this seems to be the gang mower.

High Production from Grass

The object of zero grazing management is to get the cow to eat 140–150 lb of high-quality grass each day. If the pasture is less than 6 in. it could be expected to have an S.E. of around 60 on a dry basis, so that 150 lb would provide feed for M+3 gal milk, which is the minimum one should expect to obtain under normal grazing systems. Unfortunately, if the grass has to grow to 9 in. before it can be handled, the position may be quite different. On one farm where we have taken weekly samples of the material fed to the cows under zero grazing for the full grazing period in the year, the S.E. figures we have obtained are in the range of 45–50; all too frequently they are nearer 45 than 50. At 140 lb daily intake the potential production from this grass is therefore no more than M+1 to M+1½ gal. The problem does not end there, for whenever the cow is dissatisfied she can reduce her grass intake; if this falls as low as 100 lb, then maintenance only is the potential, which for May and June is a most alarming state of affairs.

There is still a great deal we do not know about the selectivity of the cow when grazing, and it is impossible to anticipate the full consequences of taking this power away from her. Likewise, there is much to learn about the variation in feeding value of any crop after it has been grown. This can be illustrated by reference to studies carried out simultaneously on two farms in the Reading area during the last week of July 1958. Both farms practised paddock grazing, and on each farm we studied the grazing of a paddock over a period of 5 days. Samples of herbage were taken each morning before the cows commenced grazing, and on the fifth day samples were taken at 9 a.m. and again at 4 p.m.

Surprisingly, the analysis of these samples showed that over the

whole period the estimated S.E. value of the grass was fairly constant, but there was a steady fall in P.E. value over the grazing period of about 3 points in each case (9·3–6·4 at the first farm and 14·6–11·4 at the second). There was always sufficient S.E. and P.E. in the herbage to allow any cow eating 140 lb to give M+3 gal. However, on the last day of each study, when the grass was sampled morning and night and no rain fell, the dry matter figures increased by 50 per cent between the morning and the afternoon (21–30 at the first farm and 17·6–24·3 at the second). Had the cows eaten at the rate of 140 lb per day, the morning herbage would have been worth only M+2½ or 3 gal, but by the afternoon it had jumped to M+4 gal.

Assessing the Cost

We have tried to assess the costs of zero grazing on two sharply contrasting systems—one being comparatively highly mechanized, the other with equipment limited to a flail-type forage harvester, trailer, and tractor. In the first case the value of the equipment in use is £2,500, and half the time is spent on zero grazing. At 15 per cent annual depreciation the charge is £187 10*s*. As the zero grazing period is carried on over some 200 days, this works out at 18*s*. 9*d*. per day. Fuel costs 11*s*. 1*d*. and labour 12*s*. 8*d*. each day, giving the total cost of 42*s*. 6*d*., which for a herd of 135 cows works out at 3·8*d*. per cow per day. If the herd had been grazed on a routine system with an electric fence, it would have had to split in two. The task of collecting and driving these cows to the field (including moving the fence) would probably take 3 hours daily for each herd. This, at a cost of 4*s*. per hour, would give a daily total cost of 24*s*. or 2·1*d*. per cow per day. Furthermore, the cost of electric fencing would be £50 a year or 0·4*d*. per cow per day, making a total cost of 2·5*d*. per cow per day. This means that under zero grazing there is an extra charge of 1·3*d*. per cow per day which over the 200 days for 135 cows comes to £146.

The second farm used £250 of machinery for zero grazing, i.e., a £1,000 set of equipment for one-quarter of its time. This gives an annual depreciation of £37 10*s*., which works out at 3*s*. 9*d*. per day for the 200-day zero grazing period. Fuel costs were 2*s*. 9*d*. and labour 8*s*. 6*d*., because there was less mechanization. This gives a total daily charge of 15*s*. for a herd of 50 cows which comes to 3·6*d*. per cow per day. Assuming the work required on a routine grazing system to be 3 hours per day it would come to 12*s*. or 2·9*d*. per cow per day, which with electric fencing costs at 0·4*d*. would add up to 3·3*d*. per day. This means the zero grazing was costing 0·3*d*. per cow per day extra, and this over the 200-day period for the 50 cows came to £12 10*s*. in the year. But while this system may seem more economic, with the limited equipment available it would be impossible to handle the food for a much larger herd of cows.

It is emphasized that these calculations are based solely on a comparison of costs of the two methods of feeding the grass to the cows.

They do not take into consideration the extra cost of carting dung and clearing out the yards in summer time, nor do they include the cost of the extra straw which must be provided. Allowing 10 cwt of straw per cow annually and the labour at 1 hour per day for bedding and muck scraping, these costs would amount to £350 in the first case, and £130 in the second, giving a total extra charge for zero grazing of £496 in the first case, and £150 in the second. These figures are set out in detail in the following table.

An Economic Comparison of Zero Grazing with Conventional Strip Grazing

ZERO GRAZING	FARM A: 135 cows		FARM B: 50 cows	
		s. *d.*		*s.* *d.*
Mach. charges .	£187 10*s.* p.a.	18 9 a day	£37 10*s.* p.a.	3 9 a day
Fuel . .		11 0 ,,		2 9 ,,
Labour . .		12 8 ,,		8 6 ,,
		42 5 ,,		15 0 ,,
Costs per cow per day .		3·8 pence		3·6 pence
STRIP GRAZING				
		s. *d.*		*s.* *d.*
Theoretical routine work requirement .	6 hr a day .	24 0 a day	3 hr a day .	12 0 a day
Electric fence costs . .	£50 a year .	5 0 ,,	£16 a year .	1 8 ,,
Total . .		29 0 ,,		13 8 ,,
Costs per cow per day .		2·5 pence		3·3 pence
		£ *s.*		£ *s.*
Extra cost of zero grazing	1.3d. per cow per day for 200 days	146 0	0·3*d.* per cow per day for 200 days	12 10
Extra straw .	70 tons @ £4 10*s.* a ton . .	315 0	25 tons @ £4 10*s.* a ton . .	112 10
Extra cleaning of yards	200 days @ 1 hr per day . .	40 0	200 days @ 1 hr. per day . .	40 0
Total extra cost of zero grazing per annum .		£501 0		£165 0
BENEFITS	Rate of stocking increased by 20% (2·25 to 1·75 forage acres per livestock unit). 30 extra cows now carried.			

Conclusions

From these calculations it would seem that in neither of these cases did the size of herd match the machinery in use. The machinery required to cope with 135 cows could serve considerably more, and the charge per cow for machinery costs would be reduced in proportion. On the other hand, the 50-cow herd was probably too big to handle with a system that was largely manual. It is quite possible that on a small farm with 20 cows or less a system of zero grazing with the minimum amount of machinery might prove to be a less expensive method of feeding grass than strip grazing. For the medium-sized herd, however, a manual system is not applicable and there are not sufficient cows over which the machinery charges can be spread, as would be possible with a large herd.

Readers will see from Plates II and III that zero grazing is a more complicated way of keeping cows and producing milk, but it does present the prospect of increased profits through intensified stocking rates.

Modern Methods of Soil Sterilization by Steam

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DESPITE THE DEVELOPMENT of new chemical sterilizing agents, there is no doubt that steam sterilization is still the most effective way of killing pests and diseases in border soils, but its widespread use is limited because of cost and lack of equipment, particularly of a steam boiler. Although steam sterilization costs many nurserymen much more than £600 per acre, costs can be reduced considerably by employing modern techniques and equipment. With conventional methods, fuel and labour charges each represent about 40–45 per cent of the total cost, while capital charges and repairs to equipment make up the remainder. All these items are sufficiently large to make it worth considering possible savings.

This article reviews recent developments which enable nurserymen to reduce costs. As is to be expected, savings in fuel and labour costs are often only achieved by using more equipment. The increased capital charge attributable to this equipment has to be weighed against the expected savings in fuel and labour before a decision is made, but on many nurseries the additional capital outlay can be justified.

Saving Fuel

The main reasons for high fuel consumption are the use of inefficient boiler plant, the injection of steam into the soil faster than all of it can be condensed, and steaming of soil which is too wet.

Not many years ago it was general, and even today it is common, for steam to be produced from a mobile boiler, usually of the locomotive type. While mobile units can be efficient, efficiency is often sacrificed for small physical size. In addition to low efficiency, up to 15 per cent of the steam produced may be used by the induced-draught steam jet in the chimney. An electrically-driven forced-draught fan is a much more economical way of supplementing natural draught. These fan-units, normally costing less than £100, have been fitted successfully on to many locomotive boilers and have made it possible to burn coke breeze with savings of up to 20 per cent in the fuel cost compared with coal [1]. Where the same boiler plant is employed for both heating and sterilization, the greater annual use justifies installing equipment which will produce and transmit steam to the glasshouses at an efficiency of 60–75 per cent. In addition, with a steam boiler permanently on the nursery, steaming can be done when it is most convenient and soil conditions are right.

For maximum efficiency in the use of fuel the soil should be as dry as possible. The fuel required to steam wet soil is 50 per cent more for sandy soils and 100 per cent more for clay and peaty soils than when the soils are dry [2]. Some soils are difficult to break up when they are very dry, and with these the moisture content should be the minimum for easy working.

PREVENTING STEAM WASTAGE

Only steam which condenses in the soil is of use in sterilization. Escaping steam is not only wasted but makes working conditions difficult, and this increases the labour requirement. Wastage can be reduced to a minimum by controlling the rate of steam injection. The critical rate varies with soil moisture content, but for practical purposes it should never be greater than 18 lb per hour per sq. ft of border soil [3]. With high-pressure boilers and small-diameter mains, if the injection rate is correct when the full length of the main is being used it will be well above 18 lb per hour per sq. ft when the main is short, owing to less restriction on the steam flow.

Two methods are employed to prevent wastage of steam through the injection rates being excessive. In the first, known as "Balanced Steaming" [4], the plot area to be steamed at any time is chosen so that at maximum boiler output the injection rate is not above the critical rate. In this method the boiler pressure falls as the length of the main is reduced. No extra equipment is needed, but the method has two serious limitations in many nurseries. First, where steam injectors are employed on the boiler, the feed water uptake will be unsatisfactory

if the boiler pressure is allowed to fall below about 50 lb per sq. in., which could happen when the main is short. Secondly, it is not always possible to arrange to steam the correct area in all glasshouses if they are of different widths. On most nurseries employing high-pressure steam the second method, using a pressure-reducing valve unit fitted on to the down-stream end of the main, is the most satisfactory. A saving of 20 per cent in fuel has been achieved under carefully controlled conditions by fitting a pressure-reducing valve to a system where previously there was no control of steam flow [5]. Some commercial growers have found even greater savings than this.

TEMPERATURE CONTROL

When steam is injected into the soil, the surface is the last part to become hot and the first part to cool. In view of this, special care must be taken to see that all parts reach sterilizing temperature. The surface layer of soil should be free from lumps, but provided that there is at least 2 in. of fine soil at the top, large lumps below the surface will be effectively sterilized [6]. If peat is to be added to the soil, it should be placed on top of the soil and covered with a sheet before the steam is turned on. All parts of the surface do not reach 212°F at the same time. The surface immediately above the injection points becomes hot first and the surface farthest away from the injection points last [7]. Steam is wasted unless any that escapes from the hot areas is made to spread over the cold parts. Tarpaulins have been used, but they allow steam to escape through folds unless the sheet is carefully laid, limit the free use of thermometers, and are heavy to handle. Plastic sheet, preferably a heat-resisting polyvinyl chloride, weighted at the edges, is better in every way than a tarpaulin. The sheet effectively spreads steam, and when all the soil surface under the sheet is hot a stable bubble of steam will be formed lifting all the sheet except the edges [8] (Plate 1 (top)). A stable bubble is an even better indication than a thermometer that the correct temperature has been reached.

Saving Labour

On most nurseries there are opportunities for saving labour during sterilization. Labour at the boiler can be almost eliminated with automatic firing equipment. The capital investment of this in relation to the amount of annual use is high where boilers are used solely for sterilization, but where the same plant can be employed for heating and sterilization, automatic firing is generally well worth while.

The amount of mechanization of the process which is possible in the glasshouse depends upon the depth of sterilization required. There is virtually no downward penetration of steam into consolidated soil [9] and the soil has therefore to be broken up to the required depth. Where sterilization to a depth of 1 ft or less is satisfactory, the soil can be broken up with a two-wheeled rotary cultivator, with hand digging of any areas inaccessible to the cultivator. If heating pipes can

*

be moved out of the way during sterilization, hand digging can be virtually eliminated. Two types of sterilizing equipment can be used in these circumstances. Spiked pipes are relatively inexpensive, and with mechanical cultivation of the soil labour is saved compared with the buried-pipe system.

THE AUTOMATIC STEAMING GRID

An important development resulting in further saving of labour is the introduction of the automatic steaming grid or steam plough [10] (Plate 1). This system gives efficient sterilization down to the depth of cultivation. A grid of pipes similar to Hoddesdon pipes, and fitted with fins and rollers to maintain direction and depth, is drawn through previously cultivated soil, either at a pre-determined speed by a motorized winch or in steps by a hand winch. The grid is supplied with steam through a flexible hose. Although more labour is needed when the soil is steamed in steps, better sterilization is likely than with the continuous method because all the surface soil can be effectively heated under a steam-tight plastic sheet. With the motorized winch little attention is needed; the only work being at the beginning and end of each run down the glasshouse. Compared with the Hoddesdon pipe method, the total labour requirement can be reduced by about 50 per cent. Maximum savings are obtained in long, wide glasshouses free from obstructions.

THE BURIED-PIPE SYSTEM

Where depths greater than 1 ft have to be sterilized, portable buried pipes, such as Hoddesdon pipes, are almost universally employed in this country. The amount of labour needed for digging is considerable, and it is surprising that more interest has not been taken in the permanently buried pipe system used in the U.S.A. and some European countries. In this system rows of drain-pipes are laid over the whole of the glasshouse area at the appropriate depth and spacing. The pipes are covered with ash to allow even distribution of steam. Mechanical cultivation down to the ash layer is done before sterilization. Steam for sterilization is fed into the ends of the pipes. Provided that conditions are such that little consolidation takes place, the installation cost can be spread over many years. One of the limiting factors in the past on many nurseries in this country may have been insufficient boiler capacity to deal with the large plot areas. Research on this method of sterilization would be useful.

SURFACE DOWNWARDS STERILIZATION

Sterilization from the surface downwards has often been tried, mainly for convenience and to save labour compared with buried-pipe systems. In this method steam is introduced between the cultivated soil and a cover. As soon as the steam is turned on, heat is lost from the surface of the cover and if a plastic sheet is used, this cannot be insulated. Thus the efficiency of heat utilization depends upon the

time taken to sterilize to the required depth, i.e., the rate at which steam travels downwards; the greater the rate the higher the efficiency of heat utilization. The rate at which soil air can escape determines the rate of steam penetration. Where this method is employed on border soils penetration is slow, because soil air has to be expelled round the sides of the plot. In one case [11] it took 44 minutes for soil 3½ in. below the surface to reach 160°F. The rate of penetration increases as the ratio of perimeter:surface-area of the plot increases, and as the amount of air space in the soil increases. Air space can be increased by deeper cultivation. Even with careful choice of soil condition, the size and shape of the plot, and with cultivation well in excess of the required depth of sterilization, the process is always likely to be slow and wasteful of heat except where shallow sterilization is required, for example, to kill weed seeds.

RAISED-BED STERILIZATION

A similar method is being employed on some nurseries to sterilize soil in raised beds, mainly with carnation beds (Plate 1 (bottom)). This method is particularly useful where it is necessary to sterilize one bed in a glass-house while the others are in production. The beds are covered with a thin plastic sheet, and steam is introduced midway down the bed and distributed through perforated pipe such as a canvas fire hose. Condensation between the sheet and the walls of the bed forms a steam-tight seal. The rate of heat penetration downwards is determined by the ease with which the air can escape downwards. This is affected by the physical condition of the soil and the number and size of the drain holes in the bed. It may easily take 2 hours after turning the steam on for the bottom of the bed, which is usually not more than 6 in. below the surface, to reach 212°F, and in beds where air can escape only at widely spaced points, 4 hours of steaming may be needed to obtain satisfactory sterilization at all points [12]. Due to the restriction on the free escape of soil air, steam and air mix in the soil. Under these conditions temperatures between that of the unheated soil and 212°F are obtained over large zones. This is in sharp contrast to what occurs when steam is injected into the soil. In this method almost all the soil is cold or at 212°F, the transition layer of soil where heating is occurring being only about ¼ in. thick [3].

To save fuel and time during the steaming from the surface downwards it has been the practice to turn the steam off when all parts of the bed have reached at least 160°F, and so far this appears to have been perfectly satisfactory. There is not much information for general guidance on the maximum rate at which steam can be admitted without wastage when steaming from the surface downwards. This is because the rate is considerably affected by the ease of air displacement, which can vary considerably from place to place. Under some conditions a steam injection rate of 7 lb per hour per sq. ft of soil surface has been satisfactory throughout the whole of the process, while in others the

rate has had to be reduced once the surface soil has become hot. If this method is employed, the rate of steam input should be the maximum at which steam can be injected without escaping from between the cover and the sides of the bed.

Halving Fuel and Labour Costs

With improved techniques and equipment now obtainable, nurserymen are able to steam sterilize much more efficiently than was considered possible ten years ago. The savings that result from the adoption of these new methods depend upon the system at present employed, but where full use can be made of the new techniques it is possible to reduce fuel and labour costs by as much as half.

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Infestation of Grain and Feedingstuffs

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OVER THE PAST few years there has been a distinct increase in damage to farm-stored grain from attacks by insects and mites. Such attacks are not limited to grain, but extend also to feedingstuffs and hay. The increase in grain infestation is clearly associated with bulk rather than stack storage, where the major pests are rats, mice, and birds.

Nature of Damage

An outbreak of insects or mites in grain or feedingstuffs stored on a farm can cause considerable loss and annoyance. Not only is there direct loss of the food which the insects or mites consume, but indirect loss due to the effects of heating, sprouting, and attack by moulds which follow. Millable wheat may be rendered unmillable; malting barley will certainly be refused by the maltster if there is the least sign of insects or insect damage; feedingstuffs may be rendered unpalatable or less nutritious to farm animals. Furthermore, there will be the expense and inconvenience of obtaining the labour and materials necessary to carry out control once the infestation has broken out. Prevention is obviously better than cure!

Insects and Mites

Many different kinds of storage insects and mites have been found in and around farm granaries, but only a few are major pests.

It is important to distinguish these from the others since, for example, fungus beetles may be present in quite large numbers in damp grain and may cause much more alarm and unnecessary control measures than would a small number of major pests.

The important insects are *Oryzaephilus surinamensis* (L.) (saw-toothed grain beetle), *Calandra granaria* L. (the grain weevil), and *Cryptolestes ferrugineus* (Steph.) (the rust-red grain beetle (Plate IV)). Others of less importance include *Endrosis sarcitrella* (L.) (white-shouldered house moth), *Hofmannophila pseudospretella* (Staint.) (brown house moth), and *Tenebrio molitor* L. (yellow meal worm). Insects which may be numerous but do little or no direct damage include *Typhaea stercorea* (L.) (hairy fungus beetle), and *Psocids* (book-lice).

Mites, especially *Acarus siro* L. (flour mite), are liable to occur in stored grain and in feedingstuffs; large numbers of mites, especially *Tyrophagus longior* Gerr. (= *tenuiclavus* Zach.) as well as *Acarus siro*, may appear in baled hay shortly after stacking.

ORYZAEPHILUS SURINAMENSIS

The adult *Oryzaephilus surinamensis* [1] is about $\frac{1}{8}$ in. long, dark brown,

and flattened; it gets its common name from the series of serrations along each side of the thorax.

The larva moves actively in the bulk, attacking broken grains and whole grain, especially the germ, through minute breaks in the outer skin. It also attacks cereal products and oilcake. According to Howe [2] the life cycle from egg to adult can be completed between about 65°F and 100°F. At the lower temperature the period of development from egg to adult is 80 days, whereas at 90–95°F, and at relative humidities of 65–90 per cent (corresponding to moisture contents of say 14–22 per cent in wheat), it takes about 20 days. Of this only about 10 days is required for larval development. Development can also take place in very dry grain. Under optimum conditions the population can increase about 50 times a month.

The sudden onset of infestation in grain stored in buildings in which few insects were seen at time of harvest is explained by the ability of the adults to resist cold and to breed rapidly under favourable conditions. The adults live from 6 to 10 months, and can overwinter in that stage in farm buildings. Eggs are laid under favourable conditions to a total of 375 at a rate of 6–10 per day. The adults also tend to hide away in cracks and crevices in the storage buildings—a conservative estimate is 1 adult seen for every 10 actually present—but they congregate at spots of greater warmth, such as patches of sunlight, or in grain taken in directly from the field or from the drier. Grain already heating from excessive dampness is a suitable breeding ground. If some part of the bulk is at or above 65°F even for only part of a day, the breeding population may become established and, by causing insect heating to start, will rapidly produce an outbreak.

CALANDRA GRANARIA

The adult *Calandra granaria* (the grain weevil) [1] is about $\frac{3}{16}$ in. long, dark brown or black with a characteristic snout. Unlike its near relative, *Calandra oryzae* L. (the rice weevil), which may occasionally be brought on to farms with imported grain, it has no membraneous wings and cannot fly. The larva develops within single grains, from an egg laid by the female in a small pit excavated by her mandibles. About 190 eggs are laid at the rate of 1 or 2 a day over a period of 9 months. The larva moults 4 times and eventually the adult emerges from the pupa. Thus the holes seen in weevily grain show that at least one generation has bred in it.

The length of life cycle varies from 182 days at 59°F and 50 per cent relative humidity (RH) to 26 days at 86°F and 70 per cent RH. It cannot breed in grain where temperature exceeds 95°F or in wheat of moisture content (m.c.) less than 9·5 per cent. Adults are resistant to cold and survive over 100 days at 40°F and 40 days at 30°F. Immature stages have survived for 70 days at 24°F. Adult grain weevils are inactive below 50°F, pair when the temperature exceeds 53°F, and lay eggs regularly at 55·5°F and above; under experimental conditions egg-

laying occurred at 49°F. Eggs do not develop below 51·8°F although pupae will do so.

Since *Calandra granaria* is resistant to cold and commences to lay eggs at relatively low temperatures it is a potentially serious pest on farms, not only because of the direct damage but also because it can cause heating. As few as two fully-grown weevil grubs per pound of grain can start grain heating.

CRYPTOLESTES FERRUGINEUS

Cryptolestes ferrugineus (the rust-red grain beetle) [1] is about $\frac{1}{16}$ in. long, reddish-brown, and much flattened. The antennae are about as long as the body, unlike those of other small beetles in grain which are short.

The larva penetrates the germ and breeds within it, perhaps moving from one to another during development. This takes place between 60°F and 100°F being most rapid at 90°F; the insect is favoured by high humidities and in grain of less than 13 per cent m.c. population increase is slow. Rilett showed that the life cycle takes from 64 days at 70°F and 74 per cent RH (say 15 per cent m.c.) to 21 days at 90°F and 75–90 per cent RH.

The adult is very resistant to cold, being found as far north as wheat growing extends in Canada; it flies in warm sunny weather in summer. Infestation may start at slightly damp spots in the bulk of grain and cause sudden heating. The insect is imported in many kinds of cereals, cereal products, oilseeds, and oilcakes.

MOTHS

Two moths whose caterpillars cause damage to grain by destroying the germ and webbing grains together are *Endrosis sarcitrella* (the white-shouldered house moth) and *Hofmannophila pseudospretella* (the brown house moth). The former can be particularly destructive to peas and beans, destroying the contents and fouling them with droppings and webbing. Trouble has also occurred in ventilated bins by the webbing produced by the larvae blocking the holes in perforated tiles.

The *Endrosis lactella* moth is about $\frac{1}{3}$ in. long and is distinguished by white markings on the head, body, and base of the wings. The life cycle is prolonged, taking from 235 days at 50°F to 62 days at 77°F [3]. The moths which do no damage to the food live only about 10 days, and the winter is passed in the larval stage, which is resistant to cold. Populations generally build up more rapidly in foodstuffs of high moisture content.

The *Hofmannophila pseudospretella* moth is about $\frac{1}{2}$ in. long and has dark brown wings with distinct black spots. When the insect is at rest the wings are laid flat on the back. The life cycle takes from 152 to 266 days at 77°F and from 192 to 440 days at 68°F, depending on whether the larva goes into a resting stage. The moths live from 10 to 20 days. Development is favoured by damp conditions [4].

MITES

The flour mite (*Acarus siro* (L.)) [1] is about $\frac{1}{50}$ in. long with a creamy-white body and trailing hairs. It penetrates and destroys the germ of grain, directly attacks meals and other animal feedingstuffs, and taints by producing a secretion of characteristic smell. Development from egg to adult takes place between 41°F and 90°F but is considerably influenced by relative humidity, which must be above 65 per cent. The length of life cycle is from 5 months at 41°F and 65 per cent RH to 32 days at 59°F and 70 per cent and 13·7 days at 68°F and 90 per cent RH. At 59°F and 90 per cent RH the mite may live for 42 days. Mites multiply rapidly and can increase in numbers at 8 times per week at 77°F and 90 per cent RH.

Flour mites do not normally occur in grain of less than 12 per cent m.c. and do not generally prove troublesome unless it is 14 per cent or over. They flourish in damp, warm, ill-ventilated stores. On the farm, except as mentioned below, mites are mainly troublesome in animal feed.

Both the flour mite and *Tyrophagus longior* are liable to occur in large numbers in baled hay (especially seeds hay) shortly after harvest. Workers handling such infested material may suffer temporary irritation of the skin, caused by contact with the mites and their excreta. Such infestations, whilst alarming when the mites first appear, generally subside after 2–3 months, as the hay dries and becomes unsuitable for mite activity. In such cases control measures should be directed at preventing spread of mites to grain and feeds.

Origin of Infestation

Griffiths [5] has shown that the flour mite and other mites are carried with grain from the fields into buildings. The storage beetles and moths do not attack until the grain has been put into infested stores. They are normally carried to such places in some of the following ways:

1. On feedingstuffs from agricultural merchants, either directly from mills or port warehouses or through the agricultural merchant's store.
2. On grain from other farms sent for drying, grinding, or purchased.
3. On grain returned after drying elsewhere.
4. On grain sent to an agricultural merchant for grinding.
5. On hired or purchased sacks. Even new sacks which have been in contact with second-hand sacks may act as carriers.
6. On second-hand machinery brought to the farm.

It only needs one fertilized female or several larvae with grains to reach the farm for a population to be established. Sacks put into an already infested room are soon invaded, as the following extract from a report shows:

> A few hours prior to inspection a number of bundles of new sacks had arrived and had been put in the barn, where they were already getting superficially infested.*

---

* *with Oryzaephilus*

Many of the beetles are frequently found in cereals, feedingstuffs, and oilcake imported into this country, especially from the tropics.

Prevention of Infestation

Prevention of infestation in products stored on the farm falls into two categories: structural and operational.

STRUCTURAL

Storage pests generally require cracks and crevices in which to hide, unrestricted food supply in the form of grain, feedingstuffs, cereal dust and spillage, dark, ill-ventilated rooms, and lack of disturbance. The granaries, barns, and feed stores of many farms provide ideal conditions for insect development. Typical conditions were described in a report as follows:

> Beneath the flour storage is a grinder, which is in a filthy state, thick, webbed, and "Endrosis"-infested meal and broken grains being present. The floor of the small room containing the grinder is ankle deep in similar residues.

Many bulk storage installations also offer opportunities for insect development. A report on one farm read as follows:

> All the mistakes possible have been made in bin construction—too narrow deep elevator pit serving four bins; no entrance at bottom of bins; too little space between bins and walls; no ladder or steps in bins; too little head room over bins, and blower and heater next to the dusty grinder.

To which one may add failure to provide access to heating ducts for cleaning, especially in ventilated bins; no arrangements for trapping dust blown out of driers and cleaners; the use of hollow concrete blocks and failure to seal joints in grain bins.

Other structural faults include hollow floors, damp walls, and storage in warm conditions such as near farmhouse kitchens or over piggeries and cattle sheds.

It follows that all these faults should be avoided in the design and construction of farm buildings. In particular, bulk storage and drying installations should be built in such a manner that cleaning, both internal and external, is easily done and that bins are made free from cracks and crevices.

OPERATIONAL

Cleanliness and tidiness in all places concerned with drying, storage, or milling are essential. Not only does the absence of residues and dust remove insect breeding places, but such cleanliness is essential to the proper action of chemical measures of control.

As a routine measure before the new harvest all grain stores should be cleaned and the residue burnt or ground for feed. The insides of bins, walls, and floors of granaries and feed stores should be sprayed with a suitable residual insecticide.

Grain produced on the farm should be kept separate from feed, and no sacks or other gear used for feed should be used for grain or brought into the grain storage installation for any purpose. Grain brought from other farms for drying and return should be carefully examined and refused if infested. Beetles have even been found breeding in certain types of dryer.

During storage, grain should be examined regularly and temperatures recorded. Even an iron bar kept in the grain and felt for warmth is useful if a proper grain thermometer cannot be otained. A steady rise of temperature in grain known to be dry (i.e., 15 per cent m.c. or less) is a sign of insect activity, and insects should be searched for.

One farmer did not look at his grain between harvest time and November, when he found the whole surface of the barley in several bins covered with a green mat of sprouting grain, the grain beneath being hot and alive with *Oryzaephilus*. The mechanism of heating due to insect attack has been described by Oxley [6] and dealt with in Advisory Leaflet No. 404 [7].

Feeds should be stored off the floor on wood dunnage so that they remain dry. They should not be stored against the walls. The main danger here is with mites, which show themselves by a dusting round the base of the stack and give off a characteristic smell. All feeds should be examined on arrival and rejected if insects are seen.

Control

Despite precautions, infestation may occur in grain and feedingstuffs stored on the farm, and chemical control measures may be necessary. These include the use of fumigants (i.e., gases), or of contact insecticides in the form of sprays, dusts, and smokes.

The control of most farm infestations requires a combination of methods depending on the kinds of insects and their distribution in the buildings, the kinds of commodities and the extent to which the infestation has developed, and the condition of the structure of the storage buildings. The subject is dealt with generally in Advisory Leaflet 368 [8].

FUMIGATION

Bulk grain can be fumigated in most types of brick, concrete, or steel bin, provided gaps through which gas may leak can be sealed. Thus bins made of concrete blocks fitted together must have the joints pointed, similarly the joints between the plates making up aluminium or steel bins must be reasonably tight. Ventilated floor bins can be treated provided the duct can be sealed, or the grain turned to another bin whose floor has been covered with a gas-proof sheet. Bins of expanded metal can also be treated by putting an envelope of gas-proof sheeting over them.

When grain storage installations are being treated, elevators, ducts, and conveyors should be fumigated as well as the grain itself.

If the structure of the buildings is such that bulk grain cannot be treated in them, the grain can be treated in sacks.

Two fumigants can be used for farm treatments. These are a 3:1 or 1:1 mixture of *ethylene dichloride and carbon tetrachloride*, the former for very shallow bulks, for bagged grain, or for sacks, and the latter for deeper bulks, say 6 ft or more. If the 3:1 mixture is used for deeper bulks, there is a risk that the bottom part may not be effectively treated. The mixture is applied as a liquid, poured on from watering cans over the surface of the grain or stack. If grain has been heating or sprouting and is crusted or caked, such caking *must be broken up or removed* before fumigation takes place, otherwise the fumigant will not penetrate. The liquid soon evaporates to form a gas which penetrates right into the grain and kills all stages of insects and mites, even within the grains.If arrangements can be made to pour the fumigant on quickly and the space above the grain is reasonably ventilated, no special precautions are necessary. Otherwise, a proper gas mask with canister of the correct type to keep out the fumes is essential. Neglect of such precautions has resulted in some farmers having to be treated in hospital. After the liquid has been poured evenly over the surface of the grain the bin should be covered with paper or jute sacks or tarpaulins and left undisturbed for as long as possible, in any event for not less than 7 days. The normal dosage is 1 gal per 5 tons. Small quantities of fumigant should be poured into elevator casings and conveyors.

Bagged goods are treated in the same way, i.e., by pouring the fumigant on to the sacks at the top of the pile and then pulling a tarpaulin or gas-proof sheet over them. The bags should be stacked on a sheet and the top and bottom sheets should be rolled together. The best results are obtained if the bags are stacked in an upright position, rather than placed one on top of another.

For bagged grain 1 gal fumigant per ton of grain should be used for a period of at least 48 hours. Empty sacks should be treated for 48 hours at the rate of 3 pints fumigant per cwt of sacks. Small quantities of meal or grain in bitumen-lined paper bags have been successful treated by pouring fumigant into the mouths of the bags and then tying them securely.

An alternative fumigant is hydrogen phosphide. This is conveniently applied in the form of small tablets which start to decompose under the action of grain moisture after a delay of about one hour. Provided the application can be completed within 1 hour no special protective equipment is necessary. The tablets are applied at the rate of 10–15 per ton by means of a special probe applicator so that they are distributed evenly through the bulk. The bin walls need to be reasonably gas-tight for successful treatment, and it helps if the surface of the grain can be covered to exclude draughts. The grain should be left undisturbed for 5–7 days. The tablets are marketed under the trade name of "Phostoxin". Details of treatment have been described by Heseltine and Thompson [9].

Expert advice should be sought when large quantities of grain are to be treated or where the application of fumigant may not be straightforward.

CONTACT INSECTICIDES

Insects in parts of the structure not included in the fumigation may be killed by using dusts, sprays or smokes. Three materials can be recommended—DDT, gamma-BHC, and malathion. The first two can be used if the saw-toothed grain beetle is absent, since both kill a wide range of storage pests and remain effective for several weeks or months, depending on temperature, dust, and the surface on to which they have been applied. Malathion is particularly effective against the saw-toothed grain beetle [10], and gamma-BHC against mites, which are not affected by DDT. Gamma-BHC is slightly more effective against grain weevil than DDT.

The most useful formulation in farm buildings is the dispersible powder mixed with water to the correct dilution. It is stressed that the concentrations of insecticide used against storage pests are considerably higher than those used against field crop insects. These sprays are best applied by hand or by using compression knapsack sprayers or orchard-spraying gear. The object must be to cover all surfaces with the insecticide so that insects coming out from cracks and crevices must crawl over a treated surface. As a general rule sprays should not be applied to the surface of unprotected grain or feedingstuffs.

The following table summarizes the water-dispersible formulations and recommended rates of application:

Powder	Percentage of Active Ingredient in Powder	Quantity of Powder in 1 gal Spray Applied to 1,000 sq. ft Surface
DDT . . .	50	8 oz spray/gal water
Gamma-BHC . . (Lindane)	25 or 50	6 oz or 3 oz respectively
Malathion . .	25	10 oz ,, ,, ,,

As well as spray treatments used at the same time as fumigation, all farmers are strongly advised to spray their granaries, grain bins, and feedingstuffs stores after cleaning them before bringing in the new harvest. For empty grain bins with closed tops, and for ducts and other spaces difficult to reach, as well as the roof space of barns, smoke generators containing DDT or a mixture of DDT and gamma-BHC (lindane) can be used [11]. These are made in various sizes to treat from 80–7,000 cu. ft and should be used in accordance with the makers' instructions. They are essentially a means of putting a thin film of insecticide on surfaces and the smoke does not penetrate. *A smoke treatment is not a fumigation.*

BHC (lindane) dust can be used on the floors and on the surface of bagged grain to prevent the spread of mites. The actual treatment of mite-infested hay does not appear to be economical or necessary, since experience has shown that the mites disappear in 2–3 months as the hay gets dry. What is important is to isolate the hay and prevent the mites spreading to grain and feed. This can be done by using gamma-BHC (lindane) dust. Dusts should contain not less than 0·5 per cent lindane.

Grain can be protected by mixing in DDT, gamma-BHC, or malathion dust to give a concentration of about 7 p.p.m., 2·5 p.p.m., or 10 p.p.m. respectively. If grain for human (as a milled product) or animal consumption is treated, great care should be taken not to exceed these levels of mixing.

Summary

Infestation of grain stored on the farm can be prevented by attention to the following points:

1. Ensure that the grain installation is properly designed and built so that cleaning is easy.
2. Spray bins and structures before taking in new grain.
3. Keep all grain and feed stores clean and store goods in a tidy manner.
4. Refuse and send back any feeds, grain from other farms, or empty sacks on which insects are seen.
5. Do not send grain to be dried on another farm or at a grain drying installation without first making sure that it is not infested.
6. Examine the grain once a week.

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Club Root of Brassicae

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CLUB ROOT is the most widely distributed fungus disease of cruciferous crops on both farms and market gardens in this country, and economically the most important. The causal organism, *Plasmodiophora brassicae*, was identified by Woronin as long ago as 1878, and since then many workers in a number of countries have studied the disease. The net result is that there are many conflicting views on its epidemiology and on the efficiency of various control measures. Dr. J. Colhoun [1] has rendered a great service to all those concerned with the problem by preparing a monograph, which reviews nearly all the widely dispersed papers published up to 1958. This monograph and Dr. Colhoun's own investigations (some of which were described in No. 24 of this Review, pp. 179–80) do much to explain some of the divergent results obtained by different workers and to elucidate the factors which influence the incidence of the disease.

Important Factors and their Interaction

Of these factors, the following four are particularly important: the numbers of spores of the organism present in the soil, the degree of soil moisture, temperature, and soil pH. These factors are all interacting, which helps to explain the varying results obtained in different experiments in which only one factor is considered.

NUMBER OF SPORES

Some workers have found that the amount of infection increased with increase of spore concentration in the soil, while others have found no correlation. Colhoun [2] has shown that, in an acid soil, when soil moisture and temperature were favourable for infection and also for good growth of the host plants, spore concentrations within the wide range of 1,000 to 25,000 spores per gramme of soil, did not influence the number of plants which became infected. On the other hand, in an acid soil when the factors were less favourable to infection, there was a direct ratio between spore concentration and amount of infection, and this correlation always occurred in an alkaline soil. Similarly, other workers have found that the spore concentration required to cause severe infection varies with the type of soil.

SOIL MOISTURE

It is generally agreed that the disease is worse on wet land and in rainy seasons, though after infection has taken place a drought may accentuate the damage by causing wilting of the host plants with infected roots. Soil at approximately 70–80 per cent of its water-retaining capacity

appears to provide the optimum moisture for infection, but here again the severity of the resultant attack may be modified by other factors, such as temperature and soil type.

TEMPERATURE

Excessively high or low temperatures may inhibit infection, but there is a wide temperature range within which the disease flourishes. There is some divergence in the critical temperatures found by different workers, but in acid soils the minimum temperature for attack appears to lie between 10–15°C and the maximum between 30–35°C, while the optimum temperature for infection is 20–25°C. Colhoun [2] has shown that in alkaline soils the temperature range for infection is smaller than this, and also that favourable temperature persisting for up to 12 days followed by a period of lower temperature does not give heavy infection. In very alkaline soils, however, fluctuating temperature with a mean of about 23°C provided conditions leading to heavy infection.

SOIL ACIDITY

Although early workers found that the disease was often associated with acid soil conditions, other investigators have shown that this is not universally true either in the field or in critical experiments. Severe infection has been recorded in soils with pH of 7·8–8·0. On the other hand, in some instances the addition of lime to raise pH to 7·0 has reduced infection to a negligible amount. These anomalies are again most likely due to the interaction of other factors. Probably soil alkalinity alone does not prevent club root, but in an alkaline soil, temperature and soil moisture must be nearer the optimum for infection to take place, and a high spore load may be needed to produce a severe attack.

Preventive Action

How far does this understanding of the factors involved help in advising farmers to combat the disease? Spore load in the soil is most influenced by the frequency with which susceptible crops are grown on the land. Crop rotation and the destruction of weed hosts therefore play an important part in reducing or preventing the spore load from building up. Prevention is, as usual, the wiser course, for spores may remain alive in soil for at least 7–8 years, so that after heavy losses have occurred a long interval may be necessary before the spore concentration is reduced to a negligible level.

Colhoun [3] has devised a method for testing for the presence of the club root organism in the field by taking a representative soil sample and growing in it a susceptible variety of cabbage under near optimal conditions of temperature and moisture. Although the numbers of infected plants may not give a strictly quantitative result, they may provide some indication of the potential risk in a field crop if environmental conditions favour the disease. Gwynne [4] has used a modifi-

cation of this method in a survey in N. Wales, and compared the results of tests in the greenhouse with the amount of infection observed in the field. The test samples usually provided a reasonable guide as to the possibility of a severe attack on the farm.

As a high soil moisture content favours infection, improving the drainage of wet fields should assist in reducing the risk of serious loss. It will not, however, guarantee freedom from infection if other factors favour the disease. Moreover, a high soil moisture for as short a period as 18 hours, which may occur after heavy rain even with ideal drainage, can result in heavy infection.

It is obviously impossible to regulate temperature in the field, but the fact that low temperatures are less favourable to infection may be used to advantage in planning a cropping programme where susceptible crops have to be grown on a club-root-contaminated market garden. Growing autumn-planted spring cabbage, or early-spring-planted, glasshouse-raised, pot cauliflowers, may be less dangerous than summer cabbage or autumn cauliflowers, as much of the growing period of the former is at temperatures which, if not prohibitive of infection, are at least further from the optimum than they would be in midsummer.

Liming of acid soils may help to alleviate the problem, but with a high spore load and favourable conditions for infection, it cannot always be relied upon to give a good control, and husbandry considerations may place a limit on the amount of lime which can be used.

Resistance

Cultural remedies may not provide a complete solution of the problem, especially where susceptible crops are grown regularly, and it may be necessary to consider growing resistant crops or varieties.

Kale is seldom damaged by club root and may serve as an alternative to turnips and swedes in the farm rotation. If these must still be grown on land where losses are likely, the turnip varieties 'The Bruce' and 'The Wallace' may be used. In Britain, infection of these varieties is usually restricted to secondary roots, so that the bulbs give an economic yield. Other resistant varieties have been produced in Scandinavia, but little is yet known of their cropping powers in this country. In swedes, strains of the variety 'Wilhelmsburger' show some resistance, but are by no means immune. So far, resistant varieties of the market-garden brassicae, cauliflower, broccoli, cabbage, and sprouts are not available. Imported varieties which have shown resistance in their country of origin have invariably failed when exposed to severe infection under British conditions.

Chemical Control

This is the remaining defence, and here the market gardener is better placed than the farmer, as there is no economic method of treating large areas of open land required for root crops. To overcome this

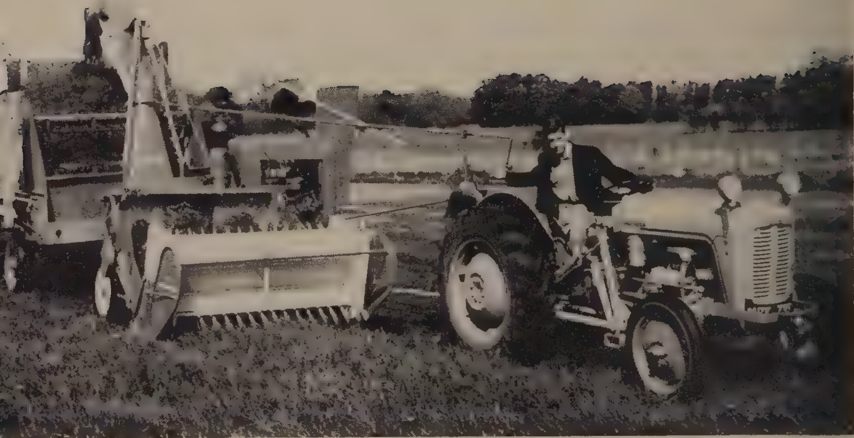
Photos: National Institute of Agricultural Engineering

MODERN METHODS OF SOIL STERILIZATION BY STEAM (See pp. 5–10)

Above : Steam sterilization with spiked pipes.
Note the bubble of steam under the plastic sheet, and heating pipes hung on the purlin posts out of the way.

Below : Steam sterilization of a carnation bed from the surface downwards

PLATE I



AN EVALUATION OF

'Using a self unloading trailer, the same man can collect the grass and feed the cows.

PLATE II

ZERO GRAZING (See pp. 1–5)

"... *the extra cost of carting dung and clearing out the yards in summer time*", and an ingenious method of dealing with the problem on Farm A.

PLATE III

INFESTATION OF GRAIN AND FEEDINGSTUFFS (See pp. 11–19)

Above left : Saw-toothed grain beetle. *Above right :* Rust-red grain beetle.

Below, left and right : Grain weevil grub and adult.

PLATE IV

difficulty, Norman, Findlay, Rosser, and Croxall [5] have attempted to apply fungicidal treatment to root crops by pelleting the seed with fungicides before sowing. Pure calomel affixed to the seed with a resin alcohol sticker at the rate of 1 lb and ½ lb of calomel per 1 lb of seed has shown some promise in reducing infection sufficiently to obtain an economic yield, but further trials are required under conditions leading to epidemic attacks.

For market-garden brassicas the comparatively small areas required for seedbeds may be treated successfully by watering with 0·05 mercuric chloride at the rate of 2 gal per sq. yard. This material may also be applied to plants after setting out, but the poisonous nature of the material and time taken to treat individual plants render this method unpopular. Growers therefore usually prefer to dip plants in a paste of 1 lb of 4 per cent calomel in ⅓ pint of water before planting out. This method has the disadvantage of sometimes giving a severe check to the plants, and is also becoming increasingly costly. Recently, Wiggell (unpublished results) has shown that the cost of the treatment may be substantially reduced by using a dip of 2 oz of pure calomel to 1 pint of water, and in one trial on sprouts he has obtained good control of the disease with only 1 oz per pint. At the 2-oz rate, although, the amount of active material used is the same as with the 4 per cent paste method, it appeared to avoid the check given to the plants.

Another interesting development is recorded by Channon and Keyworth [6], who have shown that the insecticide aldrin reduced club root infection, particularly when lime was applied to the soil. Treatment of individual plants with ½ pint of 0·01 per cent aldrin emulsion gave better results than applying it as dust at up to 8 lb per acre. In a later experiment, spot treatments of increased concentrations of aldrin up to 0·35 per cent emulsion, resulted in a greater reduction in infection, but concentrations of 0·09 per cent and over were phytotoxic. In America, good results have been obtained by using pentachloronitro-benzene preparations, but in this country Rosser [7, 8] found that the amounts required to give a control were so toxic that no increased crop was obtained. Doran [9] in America found in greenhouse tests that thiram gave a good control of slight outbreaks but was of little value against a severe attack. On the other hand, Campbell [10] found that this material and also captan gave promising results when applied at transplanting. Colhoun [11] also found that captan gave good control in greenhouse trials, but that it was phytoxic. As Colhoun [11] points out, this divergence of results underlines the necessity of using standard conditions to compare the relative merits of different fungicides. This does not avoid the necessity for field trials, but in assessing their results the level of infection in untreated controls must be considered, since materials which succeed under conditions of comparatively low infection may fail when the environmental factors are favourable to severe attacks. Further, the effect of the fungicides on the yield of the crop must be assessed so that the loss due to club root

attack is not exchanged for a similar loss due to chemical toxicity of the remedy employed.

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The Influence of Light on the Growth and Egg Production of Fowls

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THAT ARTIFICIAL LIGHTING influences the rate of egg production has been known for some time. During the last few decades the long-held opinion that the extended period of light allowed a greater food consumption and so promoted higher egg production has been discarded. It is now accepted that light exerts a stimulatory effect via the pituitary gland on the ovarian tract. But the vast amount of research work recently carried out reveals the increasing complexity of the subject. Not only are there some puzzling anomalies in the published work on light and egg production, but the inter-relationship of the rearing period and subsequent egg production consequent upon light stimuli at various stages in the cycle is by no means simple.

In 1944 Callenbach *et al.* [1] compared the subsequent performance as adults of young pullets reared under natural light with those having 24 hours light per day. The chickens subject to these differing light régimes were hatched in June. This treatment of the experimental birds resulted in the inhibition of sexual maturity and a reduced rate of egg production compared with the controls. Later, Tomhave [2] compared October-hatched chicks receiving natural light with birds hatched at the same time but receiving a constant daily light period equivalent to that of the March daylight (in Delaware). It will be appreciated that the birds receiving natural daylight were subject to a declining period of light to about 8 weeks and then a gradually increasing day-length, which approximated at the final stage to that received by the "constant light" birds. Over the first 8 weeks the birds receiving the artificial light grew better and consumed more food. But later in the experimental period they manifested delayed maturity and increased body weight but showed little difference in mortality rates, rate of lay, or hatchability compared with the controls.

There seem to be three main fields for consideration: (*a*) the variation in the amount of light received during rearing and the subsequent influence on performance after maturing; (*b*) the different lighting patterns and their effect on production during maturity; and (*c*) variations (if any) due to strain or breed.

Variations in Day-length during Rearing

From Callenbach's work already cited it is noticed that in his researches continuous lighting had no stimulatory effect on subsequent production or in promoting early maturity. Neither did a constant light

period at a lower level lead to any improvement by way of early maturity or superior egg production. Morris and Fox [3] have now advanced the hypothesis that sexual maturity is affected by *changes* in day-length and not by absolute day-length. This hypothesis would help to resolve the conflict of findings between those workers who found that artificial light advanced maturity and those who found the reverse.

DAY-LENGTH AND SEXUAL MATURITY

Morris and Fox suggest that the rate at which a pullet approaches sexual maturity is increased by increasing lengths of day and decreased by decreasing lengths of day, i.e., the most important fact is the *rate* at which the day-length is changing and not the length of the day. They found that with successive batches of chicks hatched throughout a period beginning in early June 1954 and terminating in February 1956, the earliest maturity was manifested in those birds hatched in December and the latest in those hatched in the summer, i.e., in the periods when the successive day-lengths were becoming longer and shorter respectively. As a result of the data so obtained, the authors submit a formula which predicts that in these latitudes April-hatched birds reared under constant day-length will mature about 6 days earlier than stock hatched at the same time but reared under natural daylight. But stock hatched in November will mature about 8 days later under constant day-length compared with similarly hatched birds under natural light.

MATURITY AND YIELDS

The Reading workers also subjected some of the pullets hatched over the period described to a 14-hour day from 16 weeks old and onwards, and still others to the same day-length from 30 weeks old, i.e., almost at the point of maturity. With the first group sexual maturity was advanced but seasonal variation was not entirely eliminated. This experiment is of particular interest in view of the authors' comment on the commercial value of early sexual maturity. They point out that the birds lit at 30 weeks laid on average seven more eggs than those birds lit at 16 weeks. They conclude that breeding for early sexual maturity leads to increased yields but the effect of light patterns (and possibly management) to achieve the same end tends to reduce egg production.

Morris and Fox [4] obtained confirmation of their hypothesis from further investigations. The comparison in this work was between groups of birds hatched in early December in which the controls received only natural daylight, while the experimental birds received light declining from a 24-hour day in the first week, by 35 minutes each succeeding week, until a level of 14 hr 5 min was reached at 17 weeks old. The experimental birds and controls were then housed in cages and given a uniform treatment. The performance levels showed that the decreasing

daylight inhibited sexual maturity even though the birds received more light at any stage than the control birds.

The opinion that egg production levels are dependent both on absolute day-length and change in day-length has been expressed by Sykes [5]. He found that birds receiving a 12-hour "day" produced almost double the quantity of eggs compared with others receiving a 6-hour "day" from the 12-week period. But in his experiment the time of sexual maturity of the two groups showed no material difference.

Light Patterns for Laying Stock

Many workers have reported on the effect of different light patterns with laying stock. While there is broad agreement over the opinion that light has a stimulatory effect on egg production, the degree of success achieved varies in the many experiments recorded. This may easily be due to the reasons already advanced by the workers cited above, namely both as to the period in the year when the birds were hatched and the pattern of light received between hatching and maturity. Other causes may be strain difference which are discussed later. Erasmus [6] compared groups of adult Australorps receiving ordinary daylight with groups of birds of the same breed and age but subject to a 14-hour light day. The trial began in March (Southern hemisphere autumn) and continued over 365 days. Significant increases were manifested by the lighted birds until June, i.e., over the period of declining natural light. But by the close of the full year's recording the total production from the two groups showed no significant difference, although about a dozen more eggs per bird were produced from the group receiving artificial light. Nevertheless, from the commercial viewpoint the difference gave a financial return of about 3*s*. per bird in favour of the lighted birds.

INCREASING LIGHT DURING LAYING PERIOD

King [7] gave an account of a combination of restricted lighting during rearing and steadily increasing day-lengths throughout the laying period. In his experiment the experimental birds received 6 hours light per day during the rearing period; the controls were subject to 12 hours. When housed at the 5-month stage, the experimental birds were subject to a weekly increase of 18 minutes in their daylight but the controls received a constant 14-hour day. The birds under the steadily increasing light régime showed a substantial increase in egg production compared with the control birds. It will be appreciated that these findings are broadly in accord with the conclusions of Morris and Fox.

SIMULATION OF SEASONAL REDUCTION IN DAY-LENGTH

These opinions on the greater importance of changes in day-length as compared with absolute day-length receive further confirmation from the work of Hutchinson [8]. This worker reared some Brown Leghorn pullets after 8 weeks under 23½-hour day-length and others

under a 12-hour light day. About 2 months after the two groups had come into lay, those receiving the 23½-hour day-length were subject to a gradually decreasing day-length until after 8 weeks their day-length reached 12 hours, i.e., equal to that of the control birds. The reduction or "devernalization" simulated in an exaggerated manner the seasonal reduction in day-length experienced in late summer and autumn. The effect of the "devernalization" was to induce a dramatic drop in egg production and the onset of moulting. A second "devernalization" at the end of the year had as a consequence the virtual cessation of production and heavy moulting. It will be appreciated that in this experiment the experimental birds received at least as much and usually more light at any time than the controls but that the *decline* in the amount of light had the effect of depressing production. This again confirms the hypothesis of Morris and Fox.

Experiments on Light Intensity

So far we have been concerned with length of day and not intensity of light. Staffe [9] experimented with "shock" lighting. In his work one group of birds received light of 1,500 watts at 2·4 metres at 4 a.m. for 6 sec each day during the early winter. This length was extended to 20 sec during midwinter and early spring, but in the latter period the birds were subject to a further 20 sec at 4.45 p.m. A further group of birds received artificial light at 75 watts from 4 a.m. to daybreak while a third group were subject to natural light. The second group manifested an egg production about twice as high as the controls (natural daylight); the birds receiving the "shock" light treatment were intermediate in production.

"FLASH" LIGHTING

This same subject of "shock" lighting, but called by them "flash" lighting, has been studied by Fox and Morris [10]. These workers at one time formed the view that flashes were as effective as the more usual extended artificial day so long as the flashes (given in various patterns) supplied the same total quantity of illumination, namely, 16 lumen hr/sq. ft/day, in addition to the natural daylight available. Fox and Morris did in fact secure very similar egg production levels by a series of treatments varying widely in intensity, number, and duration of flashes but all providing the quantity of illumination defined above. They did, however, draw attention to the difficulty of reconciling the hypothesis of an optimum quantity of light during the laying period with any physiological explanation, since the additional illumination is only a very small increase on the large and variable amount of light provided by a winter day.

ACTIVATION OF THE OVARY

Fox and Morris refer to work by Farner *et al.* [11] who postulated a light-sensitive mechanism capable of activation immediately upon

the onset of lighting and remaining active for some time during the ensuing darkness. The Reading workers suggest that a similar mechanism affecting the activity of the bird's ovary (rather than the gonadal development with which Farner was concerned) would offer an explanation of the flash lighting effect. On this basis flash lighting does not differ in principle from the more usual extended light system, and it would not be essential for the illumination to be so intense so long as the incidence of the flashes was correctly timed. However, as the authors point out, since no improvement in production compared with that secured by the normal lighting régime has been reported, and the cost of the flash-lighting equipment is higher than the normal method, there are no commercial reasons for recommending the flash technique.

Light of Different Colours

Several workers have reported on the effect of light of differing colours. Carson, Bacon, and Junnila [12] experimented with two strains of Columbian-patterned birds subject to light of various colours and found that, while one strain responded equally well to all lights, the second strain manifested reduced production with red light and an increased production with "cool" white. Carson, Junnila, and Bacon [13] also recorded the performance of birds reared to 15 weeks under continuous incandescent lighting, and after that stage subject to different coloured lights—still under a 24-hour day régime. In this experiment there was no evidence of any harmful effect, and all pullets receiving light of whatever colour or kind reached 50 per cent production before the unlighted controls (q.v. Callenbach, *op. cit.*). There was no evidence of any adverse effect on the sperm production of the males, in fact the incandescent lighting slightly enhanced it, especially when compared with the red and gold light treatment which tended to suppress sperm production. It will be noted that some of these conclusions are in opposition to the findings of other workers, and in view of the earlier work of Carson and his colleagues it may be that the reaction to light stimuli of strain and breed is of some importance.

Fertility and Hatchability

Several workers have investigated the effect of lighting on fertility and hatchability. Hays [14] found that all-night lighting had a beneficial effect on the fertility of cocks mated to pullets, but cockerels were little affected by artificial light. The fertility of the females remained unaffected by the additional light. Asmundson and Moses [15] extended the day-length of turkeys by the addition of artificial light. Extension of the day-length from 9–13 hours resulted in an earlier incidence of the first egg and increased egg production, but extension beyond 13–15 hours had no further improving influence. In their experiment they found no consistent effect on the hatchability of fertile eggs through lighting.

FEEDING HABITS

An interesting observation on the feeding régime of birds subject to artificial light has been made by Dubiski and Czyz [16]. They found that under natural daylight hens start to feed as soon as it is light and cease some time before sunset. With the extension of the day-length by artificial light, the birds began to feed as soon as the lights were switched on in the early morning but the artificial extension of their "day" into the evening did *not* cause them to feed over a longer period compared with the natural day. The longer day-length did, however, delay roosting.

Effect of Light on Growth of Broilers

A good deal of work has been recorded about the effect of light on the growth of broilers but literature on the subject is, if anything, more conflicting in the conclusions recorded than the work on egg-laying stock. Moore [17] experimented with broilers over 8 weeks old receiving day-lengths of 6, 12, 18, and 24 hours. The first three of these treatments were sub-divided into alternating periods of light and darkness varying from one to eight. Moore found that growth was superior when the light was given in four or six periods over the 24 hours rather than in one continuous period. Growth rate over the first three or four weeks was generally faster with those groups having the most light. Less light was needed near the eighth week.

From this work it can be concluded that over the 10 or so weeks of broiler rearing the total amount of light should be reduced from continuous day-length in the early stages of growth until by the eighth week the birds receive more darkness than light in the 24 hours. But when the bird is receiving less than 24 hours' light the period of light should be alternated with periods of darkness and not supplied in one continuous "day". The author points out that it has not yet been possible to formulate a declining light régime as the age of the birds increase to ensure maximum growth. Food conversion was a little better in those birds receiving less light, i.e., there is a certain conflict between growth rate and food conversion.

CHECKING VICES

Bowlby [18] found that sunlight and white electric light excited broilers to fighting, feather pecking, and cannibalism. With red light there was a high degree of docility while blue light resulted in the birds behaving as if they were blind. No precise data is offered for the amount of red light needed to cause elimination of the vices mentioned without loss of food intake by the birds. Five feet of 80-watt red fluorescent tube at 8 ft per 720 sq. ft is suggested. The author also reports beneficial results from the gradual reduction in the total amount of light per day and supplying the day-length in alternating periods of light and dark.

Many Problems Still Unsolved

It will be appreciated from this brief review that the problem of the influence of light on poultry is one of some complexity. Recent work has resolved some of the conflicting findings of earlier works; but many problems remain unsolved. In broad terms it can however be stated that a gradual increase in the day-length is desirable for birds for laying purposes; the reverse is indicated for broilers. But even this is an oversimplification.

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Scientific Principles of Livestock Feeding: Part III*

(Concluding a summary of the papers presented at the Brighton Conference, 11–13 November, 1958)

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The Breeding Pig

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FEEDING THE GROWING GILT

Unsuitable feeding during the rearing of the gilt may delay sexual maturity and reduce fertility. Some American work showed that numerically largest litters are obtained by restricted feeding to puberty, self-feeding from puberty to mating, and again restricted feeding during pregnancy (restricted = $\frac{2}{3}$ self-feeding level). It seems likely that the normal "sow and weaner" meal to 120 lb and the normal "fattening" meal thereafter provide about the right amount of protein. There is no knowledge of any special need for minerals or vitamins above the ordinary.

PREGNANCY

The pig takes two years to reach mature weight, so feeding during the first two pregnancies must include an allowance for growth.

The demands of pregnancy, as in other species, appear to be small until the final few weeks, but throughout this period protein is stored in the body at a fairly constant rate. This may be due to replacement of body tissue lost during the previous lactation and about to be lost again in the early weeks of the next. Vitamin A and riboflavin are particularly important in early pregnancy to prevent malformation of the foetus.

In Table 1 an allowance has been made for growth at $\frac{1}{2}$ lb per day up to 500 lb but not thereafter, hence the allowance drops at that point. The theoretical values listed require confirmation by practical trials before acceptance.

With regard to the quantities of meal quoted in Table 1 opposite, there is no need in theory for the crude protein to exceed 12 per cent of the meal (as digestible crude protein, 10 per cent). However, the *quality* of the protein is very important, and the inclusion of fish meal to the extent of 10 per cent of the diet seems to increase slightly the piglet size and survival rate.

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Table 1
Total Feed Requirements of Pregnant Sows
(i.e., for body growth (where appropriate), maintenance, litter growth, and mammary growth)

Live weight	Daily Meal Requirement*	
	Mean	Maximum
lb	*lb*	*lb*
300	5·5	5·9
350	6·0	6·3
400	6·4	6·8
450	6·8	7·2
500	5·7	6·1

* Assuming 1,350 Kcal of digestible energy per lb meal.

It is suggested that an adequate intake of calcium and phosphorus is attained on a daily consumption of 5–6 lb meal containing 0·6 per cent Ca (0·84 per cent CaO) and 0·3 per cent P (0·69 per cent P_2O_5). Apart from the need for iodine in goitrous areas, there is no evidence that the pregnant pig needs more trace elements than the growing pig.

Deficiency of vitamins at one stage of foetal development cannot be made good at a later stage. The requirement of 3,000 I.U. vitamin A per 100 lb live weight, or 4 mg carotene, can easily be obtained from grazing. There is no information on the requirement of vitamin D, but it is assumed that 90 I.U. per lb of food is required as for the growing pig. The riboflavin requirement is met by 1·25 mg per lb of food, and this is covered by the usual meals and by grazing.

LACTATION

It has been found that a sow suckling eight pigs and maintaining her weight converts 45 per cent of the digestible energy of her feed into milk energy. On this basis the following has been calculated:

Table 2*

Litter Size	Daily Meal Requirements according to Sow's Weight			
	350 lb	400 lb	450 lb	500 lb
	lb	*lb*	*lb*	*lb*
6	13·4	14·0	14·5	15·1
8	15·2	15·7	16·3	16·9
10	17·0	17·5	18·1	18·6
12	18·7	19·3	19·9	20·4

* Adapted from the original Table 6.

These quantities much exceed the amounts given in practice, and this explains the usual large losses in sows' weight. Sows given 8 lb meal plus 0·8 lb per piglet produced a fifth more milk than those given 2 lb plus 1 lb per piglet, but the weaning weights were only slightly better (39·3 lb against 37·7 lb). The effect of the lower level of feeding was apparent only after the third week, by which time the piglets were beginning to take a creep feed, and the low-level pigs took more of this. The lower plane of nutrition did not affect the sows' fertility over three pregnancies and lactations, and, in any case, much of the extra weight was lost by the high-level sows after weaning. It is concluded that about 3 lb plus 1 lb per piglet is a reasonable practical level for the suckling sow.

Theoretical protein requirements cannot yet be calculated for sows with different sizes of litters. Fifteen per cent crude protein in the diet seems to be sufficient to allow some storage of body protein in the sow suckling an average litter, provided that enough meal is eaten to maintain body weight. But body weight is not normally maintained, and the optimum protein level, when body tissue is being broken down to provide energy, is not known. However, 16 per cent of crude protein appears to be safe at all feeding levels.

A sow eating 12 lb meal and yielding 18 lb milk requires 0·6 per cent Ca (0·84 per cent CaO) and 0·4 per cent P (0·92 per cent P_2O_5) to cover maintenance, milk, and incomplete absorption from the gut. These amounts are easily reached in ordinary formulations. The vitamin requirements are assumed to be the same as those for pregnancy.

The Rearing Period

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The end of the rearing period may be taken to be the attainment of 45 lb live weight. It is desirable that this should be reached in 8 weeks, but longer may be required.

Lucas expresses the requirements for protein, amino-acids, and B vitamins in terms of weight per 1,000 Kcal of digestible energy. This is because it is the intake of digestible energy which limits growth if the diet is well balanced, and protein and B vitamins need only keep pace with the energy. On the other hand, skeletal growth does not stop unless the fall in energy intake is very marked, hence minerals are related more to body weight and this is true also for the fat-soluble vitamins. In consequence, the fat-soluble vitamins are expressed on the basis of live weight and minerals in terms of weight per lb feed dry matter.

Calculations on these lines require assumptions to be made about the percentage of dry matter in the mixed diets, the chemical composition of the diets (calculated from the average composition of the components), the gross energy calculated from the chemical composition, and finally the digestibility of the gross energy. By such operations it was possible to express the fundamental requirements of

the piglet in the forms laid down in the preceding paragraph. Further calculation converted the figures into the more practical terms of "weight of nutrient per lb of diet as fed" and some of these are shown in Table 3. Here the diet for pigs of 3–10 lb is of a type made up with water to form a synthetic milk substitute, and the high proportion of fat (over 15 per cent) confers a high calorific value. The meal for pigs of 10–20 lb is semi-synthetic and contains up to 5 per cent fat and 15 per cent sugar. That for 20–45 lb is non-synthetic, containing only "normal" feedingstuffs such as fishmeal, soya and cereals; it would have a T.D.N. (total digestible nutrients) value of about 75.

Table 3*

Minimum Levels of some Nutrients in Diets for Young Pigs

(assuming that pigs of 10, 20, and 40 lb live weight eat 0·5, 1·2, and 2·2 lb dry matter daily)

Nutrient	Unit	Live Weight		
		3–10 lb	10–20 lb	20–45 lb
Digestible energy	Kcal per lb	2,175	1,625	1,525
Dry matter of diet	per cent	95	90	87
Crude protein†	per cent	29·7	19·3	14·4
Digestible crude protein†		28·7	18·6	14·1
L-Amino acids:				
lysine		1·34	0·86	0·64
methionine + cystine		1·08	0·69	0·52
Thiamine	mg per lb	0·87	0·65	0·61
Riboflavin		1·09	0·81	0·76
Nicotinic acid		9·80	7·30	6·90
Pantothenic acid		6·30	4·70	2·60
Pyridoxine		0·43	0·32	0·30
B_{12}	μg per lb	8·70	6·50	4·60
Vitamin A		130	130	55
or Carotene		390	390	330
Vitamin D	I.U. per lb	100	100	90
Ca or CaO	per cent	?	?	0·52 or 0·73
P or P_2O_5		?	?	0·38 or 0·87
Common Salt		?	?	0·26
Iron	mg per lb	95	90	74
Copper		10	9	9
Zinc		?	45	45
Magnesium		?	140	140
Manganese		?	18	18

* Modified from the original Table 12. † See notes overleaf

NOTES ON TABLE 3

† The figures apply to protein from cow's dried milk, or casein. When the protein is obtained from a mixed ration, the levels should be increased by one-third for pigs of under 35 lb and by one-seventh for pigs over 35 lb.

The requirements for 9 amino-acids are given by the author although only two have been quoted.

The requirements stated for vitamin A allow for a slight liver storage which requires more vitamin than is needed for merely good growth and avoidance of deficiency symptoms.

CARBOHYDRATES AND FATS IN DIETS FOR YOUNG PIGS

Only glucose of all the sugars can be tolerated at all ages from 2–56 days. Lactose is well used at first but after 4 weeks intestinal lactase declines, and by 40 lb live weight a feed containing 50 per cent lactose slows growth and causes scouring; this is found with dried whey, for example. After the first weeks maltose can be utilized and starch can be digested adequately by 3 weeks or so. Sucrose causes scouring in the first week but is tolerated as 20 per cent of the diet after a fortnight.

Fat deficiency symptoms have been observed in 35lb pigs kept on diets with only about 0·1 per cent ether extract, but practical diets have many times this quantity. Most milk substitutes for 2-day-old pigs have had about 27 per cent lard. Meal mixtures with as much as 13 per cent ether extract are noticeably oily; 5 per cent is commonly used from 10 to 20 lb live weight.

When pigs are weaned at 10 days their energy intake is nil for the next half-day and remains below that of suckled pigs for the next fortnight. After the fourth or fifth week the lost ground is regained and intake and growth rapidly increase.

SUCKLING AND CREEP FEEDING

The yield and composition of sow's milk have been averaged for 24 lactations and the following figures obtained:

Table 4*

Week of Lactation	Daily Milk Yield	Protein	Lactose	Fat	Ash	Total Solids	Calculated Gross Energy
	lb	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*Kcal per lb*
1	14·9	5·5	4·9	9·0	0·8	19·9	608
2	20·3	5·0	5·0	8·6	0·7	19·5	576
3	21·2	5·3	4·9	9·7	0·8	20·8	631
4	19·5	5·4	4·8	8·9	0·9	20·1	599
5	19·6	5·7	4·7	8·8	0·9	20·4	599
6	18·4	5·9	4·6	8·2	1·0	19·8	576
7	14·6	6·2	4·6	7·9	1·0	19·7	572
8	13·3	6·6	4·6	7·7	1·1	19·8	572
Mean	17·7	5·7	4·8	8·6	0·9	20·0	591

* Adapted from the original Table 15.

Readers will see that maximum yield and energy value have been reached by the third week and both remain high until the fifth or sixth week. By that time the growing piglet is making good use of the creep feed.

Sow's milk contains only about 1 mg of iron per lb and this cannot be increased by feeding extra to the sow. If piglets have no access to soil they must be given iron by mouth or by injection. A single injection is sufficient for 3 weeks, but dosing by mouth should be done at 3 days old and repeated weekly until creep feed is being taken.

Table 5 shows the quantity of creep feed required to supplement sow's milk and was estimated from the average amounts of milk available and the daily requirements of the piglets. It is assumed that the gross energy of the milk is 95 per cent digestible and that the mean litter size is 8·8.

Table 5*

Age	Weight	Digestible Energy			Calculated Daily Requirement of Creep Feed†
		Daily Requirement	Supplied by Milk	Required from Creep Feed	
Weeks	*lb*	*Kcal*	*Kcal*	*Kcal*	*lb*
1	6	950	950	—	—
2	9	1,250	1,250	—	—
3	13	1,625	1,400	225	0·2
4	17	2,000	1,250	750	0·5
5	22	2,375	1,250	1,125	0·8
6	28	2,750	1,150	1,600	1·1
7	35	3,125	900	2,225	1·5
8	42	3,500	800	2,700	1·8

* From Table 20 of the original.
† For a creep feed with 1,525 Kcal digestible energy per lb of air-dry food, i.e., with a T.D.N of 75.

It is considered that 1 per cent of each of CaO and P_2O_5 in the creep feed is sufficient to supplement the milk's contribution. The average vitamin content of milk exceeds the requirements except in the case of B_{12} and pyridoxine, but since fluctuations about the average may be large it is wiser to provide for the full vitamin needs through the creep feed.

Obviously, recommended allowances include minimum requirements and margins of safety. Unfortunately, margins of safety depend upon variations in the demand for nutrients under different circumstances, upon the efficiency of metabolism, and upon variations in chemical composition and in protein quality due to manufacturing processes. It is not yet possible to provide scientific guidance on how large margins of safety should be.

An example of the effect of environment is the increased demand for B vitamins which accompanies the increased expenditure of energy in conditions of cold.

The protein requirements in meal mixtures containing fish meal, dried milk, soya bean, and cereals are shown in Table 6.

Table 6*

Type of Pig	Crude Protein in Meal Mixture (87 per cent dry matter assumed)
	per cent
Early weaned:	
10–20 lb . . .	25·0
20–35 lb . . .	18·7
35–45 lb . . .	15·7
Suckled pig, creep fed:	
4 weeks old, 17 lb .	22·2
5 ,, ,, 22 lb .	17·1
6 ,, ,, 28 lb .	17·1
7 ,, ,, 35 lb .	14·5
8 ,, ,, 42 lb .	14·5

* Adapted from Table 23 of the original.

A good creep feed with 20 or more per cent crude protein and a T.D.N. of 75 would be sufficient for all types, with the exception of the early-weaned 10–20 lb pig, which requires distinctly more protein (at least 25 per cent) and energy (a T.D.N. of 80). Such a pig would be given a ration containing up to 5 per cent fat and 15 per cent sugar.

Feeding Standards for Growing-fattening Pigs

R. Braude: National Institute for Research in Dairying

Braude begins with a discussion of the limitations of feeding standards. He warns that they are at best only guides and can never be universally applicable. Proteins deficient in essential amino-acids, vitamins in unavailable forms (as for example nicotinic acid in maize), interactions between minerals (such as Ca and P or Ca and zinc), variations in the composition of cereals, palatability, previous nutritional history of the animal—these and many other factors introduce difficulties.

Tentative guidance on the requirements of growing and fattening female and castrated male pigs, which requires confirmation before acceptance without reservation, is given in Table 7.

Table 7*

Weight	Daily Gain	Weight of Feed (88% dry)	Weight of Feed per lb Gain
lb	*lb*	*lb*	*lb*
50	0·97	1·8	1·9
75	1·25	2·4	1·9
100	1·50	3·1	2·1
125	1·73	4·0	2·3
150	1·95	5·1	2·6
175	2·03	5·8	2·9
200	1·95	6·5	3·3
225	1·75	7·0	4·0

* Adapted from Table 4 of the original.

EFFICIENCY OF FEED UTILIZATION

Under conditions at the National Institute for Research in Dairying, best results with bacon pigs have been obtained by fixing the ceiling at 6·5 lb per day; but the optimum in co-operative work at another centre was 5·5 lb. To some extent the efficiency of feed utilization depends upon growth rate. The higher the growth rate, the less feed required for maintenance. More important is the *caloric* value of the weight gain. As the pig grows older more fat is laid down, and this requires much more feed in view of the high calorific value of fat. Temperature of the environment and the degree of exercise are other factors affecting the maintenance requirement.

BODY AND CARCASS COMPOSITION

There is no significant difference in body composition between different types of pig at birth and up to 90 lb weight, but at 220 lb there are marked differences between the bacon type and the fat type. This is shown in Table 8.

Table 8*

Type and Size	Water	Protein	Fat	Ash
At birth (bacon type and fat type)	81·5	12·4	1·9	4·2
At 80–90 lb (bacon type and fat type	58·5	13·0	25·4	3·1
At 220 lb (bacon type)	50·1	13·5	33·3	3·1
At 220 lb (fat type)	45·4	11·9	40·1	2·6

* Adapted from Table 5 of the original.

The level of protein feeding may have an effect on carcass composition. In one experiment, a diet rich in protein resulted in 1 per cent more protein and 5 per cent less fat than a protein-poor diet.

EFFECT OF FEED RESTRICTION

When pigs were fed on a scale up to a maximum of 6·5 lb they took slightly longer to reach bacon weight than did pigs on a semi-*ad lib.* system which allowed them to eat all they could clear up in two periods of 20 min each, up to a maximum of 6·5 lb per day. However, the pigs fed to scale showed better gradings and food conversions.

There is no satisfactory evidence about the quantities of water required by fattening pigs. A ratio of 2½ parts of water to 1 of meal is probably as good as the more common 3 to 1 ratio. There is a widespread belief that *ad lib.* water is detrimental to carcass quality of bacon pigs but this is without sound evidence.

EXISTING STANDARDS

The National Research Council recommendations for protein and energy refer to the husbandry conditions of the United States, and their values for minerals and vitamins are means based on widely-ranging individual values. Such values are only rough guides and require judicious interpretation in particular cases.

The current British standards for protein, i.e., 17 per cent for the weaner, decreasing to 13 per cent in the final stage of fattening, are considerably higher than those of European workers. However, amino-acid composition is more important than protein percentage. A ration with 12 per cent protein could be better than one with 18 per cent if the balance of essential acids were correct in the first and not in the second.

Evans' work showed that a standard diet containing 7 per cent of fish meal in addition to barley, fine bran and lucerne meal, seemed to be just borderline in lysine content for optimal growth rate up to 90 lb. It contained 0·76 per cent lysine and the improvement obtained by adding more lysine was too small to justify the practice. Fifteen per cent of soya bean meal was practically as good as the fish meal, but 20 per cent of groundnut meal was still slightly deficient in lysine. It appears therefore that 7 per cent of fish meal (perhaps with some vegetable protein for good measure) provides adequately for the growth of weaners to 90 lb. Between 90 and 150 lb lysine requirements appear to be halved and the need for animal protein largely disappears.

PRACTICAL CONSIDERATIONS

Rather than attempt to lay down standards in terms of energy units, etc, Braude considers that there is a great deal of experience already collected from the use of practical meal rations upon which sound advice can be based. With a reference protein such as fish meal, and reference cereals such as barley and wheat offals, intelligent substitution can be made as desired. Minerals and vitamins are mainly proprietary articles to be used on the maker's instructions.

There are three feeding methods which require to be catered for:

(1) meal ration throughout;
(2) meal ration used with fodder beet, potatoes, swill, whey, etc; and
(3) cereals plus skimmed milk.

Four meals would be sufficient for the above methods. These are shown in Table 9.

Table 9*

Percentage Composition of Meal Mixtures for Growing-fattening Pigs

	A	B	C	D
Cereals	92	95	88	98
Animal protein supplement	7	—	10	—
Vegetable protein supplement	—	3	—	—
Mineral supplement	1	2	2	2
Vitamin supplement†	++	+	++	+(+)
Growth-promoting additives‡	×	×	××	×

* Modified from Table 17 of the original.
† Vitamin A 2,000 I.U. and vitamin D_3 500 I.U. per lb.
‡ Antibiotics, copper sulphate, etc, if desired.

Method (1) would be used for porkers to be slaughtered at 100–140 lb, and for baconers to be slaughtered at 200–210 lb. The porkers would receive mixture A *ad lib*. Baconers would receive A to 125 lb, followed by mixture B; the feeding to be restricted according to a scale, such as that of Table 10.

Table 10*

Feeding Scale for Growing-fattening Pigs

Live Weight	Meal per Day	Live Weight	Meal per Day
lb	*lb*	*lb*	*lb*
35	2·0	110	4·5
50	2·5	125	5·0
65	3·0	140	5·5
80	3·5	155	6·0
95	4·0	170 (and over)	6·5

* Modified from the original Table 18.

If method (2) were employed, mixture C would be given up to a maximum of 3 lb per day with the bulky food to appetite. Baconers could be produced with high-quality bulky food, but the method is most suitable for the heavy hog trade.

Method (3) with mixture D produces porkers and bacon pigs. The most economic returns are obtained with about 6 pints of skim milk.

Braude concludes with a reference to the German practice (under

the *Deutsche Landwirtschaftliche Gesellschaft*) of annually reviewing the formulation of rations and permitting the use of an approved mark to indicate those which conform to prescribed standards. He feels that such continuous supervision has merit and he would like to see stations established in the United Kingdom for testing practical rations.

Regional Note

Fertile Acres from Barren Waste

P. W. MILLIGAN

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IRTON MOOR, to the north-west of Scarborough, lies at a height of 600 ft above sea level. The surface vegetation on this moorland previously consisted of stunted birch and heather with a few patches of Nardus and Molinia. There had been no livestock on the area in living memory, except for dogs and trekking ponies from the local riding schools, so that the heather stands were waist high in many places. The area had been earmarked at one time for Scarborough airport, but for a number of reasons was unsuitable. In 1949, a local farmer and District Committee member asked the N.A.A.S. to examine the possibilities of cropping this land. The first attempt at reclamation was started on about 20 acres which had been cleared by campers' fires just after the war, and during the past ten years the N.A.A.S. has been closely associated with its development.

The soil, which is formed from lower oolitic limestone, is best described as a Moor Podsol. Soil samples were taken, and the first results from the soil chemist were not encouraging:

pH	Lime Requirement CaO	Phosphate	Potash
3·8	50 cwt/acre	Very low	Medium

This information suggested that oats, rye, and potatoes offered the greatest chance of success. The farmer disliked rye but had some experience of seed-potato production. It was therefore decided to crop

some 16 acres with 'Victory' oats and 4 acres with 'Bintje' potatoes. A dressing of 50 cwt per acre of burnt lime was recommended, but 50 cwt per acre of ground limestone was applied in error. The result was a complete failure of the oat crop due to lime deficiency. The potatoes, however, were a first-class sample of S.S. 'Bintje', yielding 5 tons of seed and 2 tons of ware, per acre.

Two lessons were learned from the first year's work. First, that a good furrow was necessary to bury the heather and rubbish. This meant that all the organic matter, which was concentrated in the top 3 in. of original land, was deposited at a depth of 10 in. The exposed surface of the furrow was completely devoid of organic matter.

The second, and more important lesson was that the organic matter took a very long time, certainly more than a year, to form humus. While mineral and organic matter could be mixed, this itself did not form a soil capable of supporting plant life.

As a result of these lessons, it was decided that in any future programme a pioneer crop should be introduced. Cultivations stopped in 1951 due to the untimely death of the owner, but a purchaser was found and preparation for the 1952 crop began. The whole area was reploughed and worked again for oats; a further 50 cwt per acre of burnt lime and 4 cwt per acre of complete fertilizer (10:10:15) were applied. The whole area was undersown with grass seed, using three mixtures as follows:

		lb/acre
1.	Cocksfoot S.37	3
	Timothy S.48	4
	Meadow fescue S.53	6
	White clover S.100	1½
	Wild white clover S.184	½
2.	Perennial ryegrass S.23	6
	Irish commercial ryegrass	4
	Cocksfoot S.26	6
	Cocksfoot S.143	4
	Timothy S.51	4
	Late flowering red clover S.151	4
	White clover S.100	1½
	Wild white clover S.184	½

3. as "2" using all commercial strains of grasses.

The oat crop was successful, yielding approximately 15 cwt per acre, and the "take" of grass seeds was good. An interesting feature was that some of the virgin moor was cropped in squaring up the area, and on this portion the grass seeds were virtually a failure, in spite of full lime and fertilizer treatment. A further block of land was also taken out and put into a pioneer crop of:

	lb/acre
Rape	6
Ryegrass	10
Hardy yellow turnips	2

The leys and pioneer crop were grazed with sheep in the autumn, winter and early spring. Most of the hoggs were fat enough to sell, while the ewes produced a first-class crop of lambs.

In 1953, part of the grass was put up for hay, and the land under the pioneer crop was sown to oats. The yield of hay was 35 cwt per acre, while the oats cropped at 24 cwt per acre, a sure indication that the pioneer crop was justified.

Pioneer Cropping

As a result of this success, suitable pioneer cropping was decided. The possibilities were:

(*a*) alternative types of crop;
(*b*) two crops in one season; and
(*c*) grazing versus ploughing-in.

The use of rye and ryegrass was examined as an alternative crop to rape, ryegrass, and hardy yellow turnips. The cost of the original mixture was favourable, and rye appeared to contribute little to the summer and autumn growth.

The possibility of sowing two crops in the season appeared sound, but unless the first sowing could be made early in the season, growth from the second crop contributed little to the winter keep unless sown in late June. In practice a much greater stocking would be obtained by a single seeding left to grow on.

The question of discing in the pioneer crop as opposed to eating it off was considered, but it was felt that the grazing animal was likely to contribute considerably to the improvement of the soil texture and it was decided that, wherever practicable, grazing should take place.

Rotations

In the earlier days of the reclamation a standard rotation of pioneer crop, oats, and 3-year ley, was introduced.

It might well be argued that the ley should have been sown immediately after the pioneer crop, and latterly this has been done, but the scheme was being privately financed without Marginal Production Scheme assistance, and the contribution of even a light crop of oats was to be welcomed. Experience with the ley mixtures mentioned earlier suggested that the Cockle Park mixtures were the most suitable, with advantage lying very much in favour of the leafier-bred strains, even allowing for the greater cost. It was hoped to graze the leys with cattle, but as the problem of a water supply was only overcome later, this was impossible and the choice had to be sheep grazing and hay cropping. Fertilizer application to the leys was 3–4 cwt per acre of 9:9:15 with 10 cwt per acre of basic slag in the second autumn.

In 1956, the first of the long leys was broken to an oat crop. This time the variety 'Blenda' was chosen, and a yield of 30 cwt per acre was obtained. Further ploughing-out of other leys in 1957 and 1958 has

given similar yields. Crops of potatoes both for seed and ware have been grown, giving yields of 10 tons per acre.

Nearly two hundred of the three hundred acres of moorland are now under normal farming cultivation and this achievement has also proved economic, particularly with the assistance of the Marginal Production Scheme in the mid-1950s.

Discussion

Many problems arose during this work, some of a purely mechanical nature, some of the physical soil complex, some chemical, some of pure husbandry. Their significance and solution may be of assistance to others undertaking similar tasks.

Heather is much more tractable if it can be burned, and firing the heather and scrub allows a single furrow plough to work satisfactorily. Scrub roots and heavier timber can be dealt with either by tractor and chain or bulldozer, but the latter method is only economic where the scrub is both heavy and thick, and it generally leaves rather difficult terrain for tractor and plough to follow. A muck-loader, particularly of the short-coupled, rear-loading variety, is an ideal tool for gathering up cleared stumps for burning.

Humus, and its formation from raw organic matter has already been mentioned. The matted vegetation does not break down for some time, even after the application of lime and fertilizer, so that the retention of soil nutrients in the initial stages of reclamation is not great. It is therefore essential to feed the pioneer crop generously in its first few months. Later, when stock can be got on to the pioneer crop, smaller dressings of fertilizer, particularly of nitrogen, give satisfactory results. It is believed that this is due in some way to the establishment of the soil bacterial flora and root nodulation later in the clovers but this takes time, and attempts to reduce the time-lag have so far proved unsuccessful. The importance of stock in this connection cannot be overestimated since, quite apart from the deposition of dung by the animals, their treading does much to incorporate the organic matter with the mineral matter to form a soil. Though no statistically sound information is available, there is no doubt that visually the areas in pioneer crop and grazed were giving heavier crops than those areas which had been disced. The increase appeared to be about 20 per cent.

Providing phosphate and potash in the form of bag fertilizer is straightforward. Liming, however, is critical. Lime is best applied after the first seedbed has been prepared and again either for the second pioneer crop or for the second year's crop, whether cereal or ley. The double application is preferable to a single heavy dressing but overliming must be guarded against. Some symptoms of magnesium, cobalt, and copper deficiencies appeared in parts of the moor in the last year, and these can be traced to a history of overliming. The soil chemist now advises the use of magnesian limestone on this area.

The latest soil sample results are:

Field No.	pH	Lime requirement (CaO)	P_2O_5	K_2O	MgO	Cu	Co
		cwt/acre			*p.p.m.*	*p.p.m.*	*p.p.m.*
1	6·1	20	Low	Good	< 50 Low	0·175 Low	0·05 Low
2	6·2	—	Low	Good	< 50 Low	0·45 Low	0·15 Low
3	5·6	20	Fair	Fairly Good	< 50 Low	0·63 Medium	0·34 Low
4	6·1	—	Fair	Good	< 50 Low	1·15 Satisfactory	0·25 Low

Husbandry problems include choice of crop and management. Rye and ryegrass as an alternative pioneer crop to the rape and ryegrass has been suggested, but the cost of rye in relation to yield does not appear to justify its use. Barley, as a first crop after the ley has not proved successful. Of the oat varieties, the more highly yielding 'Blenda' is very useful: in spite of a difficult season in 1958 a crop of 30 cwt per acre was harvested.

An attempt to grow potatoes after two pioneer crops has shown that the soil has not been stabilized sufficiently, so that cultural difficulties arise with the row ploughs being drawn into the subsoil in places. This did not occur after the three-year ley. Seed-potato production is possible; in 1959 about 40 acres of seed potatoes were produced.

This work has shown that an extensive potential source of cultivable land still exists in the lower moors of the north of England. These barren lands can be turned into fertile acres and replace much of the good land being used for building in other parts of the country.

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